generated in the first underlying layer **42** on the substrate surface side and large positive polarization is not generated on the buffer layer **41** side as shown in FIG. **22**. In the nitride semiconductor device according to the present embodiment shown in FIG. **19**, degradation of the pinch-off characteristics can be prevented.

[0110] If the In composition ratio T in the first underlying layer **42** is at least approximately 0.52, the band gap is greater than the buffer layer **41** formed of the GaN film and the influence of carriers remaining in the buffer layer **41** can be prevented as shown in FIG. **25**. In the nitride semiconductor device according to the present embodiment shown in FIG. **19**, therefore, the pinch-off characteristics can be improved.

[0111] The degree of lattice mismatching to the buffer layer **41** formed of the GaN film and the band gap can be changed by changing the composition ratio (1-S) of Ga in the first underlying layer **42**, as shown in FIG. **25**. If the composition ratio of Ga is made large, the lattice mismatch to the buffer layer **41** formed of the GaN film (value of the abscissa axis shown in FIG. **25**) becomes small and the first underlying layer **42** can be formed with a good film quality. If the Ga composition ratio is made small, the band gap difference from the buffer layer **41** can be made large and consequently the influence of carriers remaining in the buffer layer **41** can be excluded efficiently. If the In composition ratio T is thus in the range $0.3 \leqq T \leqq 0.52$, the Ga composition ratio can be freely changed according to characteristics required of the semiconductor device.

[0112] For raising the conduction band energy in the channel layer **44** and improving the pinch-off characteristics, it is necessary to generate negative polarization charges on the channel layer **44** side in the second underlying layer **43** as shown in FIG. **20**. Since the In composition ratio Y in the second underlying layer **43** formed of an $(In_YAl_{1-Y})_XGa_{1-X}N$ ($0<X \leqq 1$, $0 \leqq Y<1$) film is 0.3 or less, negative polarization charges can be generated on the channel layer **44** side in the second underlying layer **43** because of dependence of the polarization charge density upon the composition ratio shown in FIG. **22**. Therefore, it becomes possible to form a nitride semiconductor device which is excellent in pinch-off characteristics. If at this time the first underlying layer **42** is formed of an $(In_TAl_{1-T})_SGa_{1-S}N$ ($0<S \leqq 1$, $0<T \leqq 1$) film, it is desirable that T>Y. In the same way as the first underlying layer **42**, the Ga composition ratio can be freely changed according to characteristics required of the semiconductor device as shown in FIG. **26**.

[0113] If the lattice constant in the second underlying layer **43** in a direction perpendicular to the stacking direction from that of the GaN film of the buffer layer **41**, strain is caused so as to make the lattice constant the same as that of the buffer layer **41**. If the buffer layer **41** is formed of the GaN film and a film having the same lattice constant as that of the GaN film is used as the second underlying layer **43**, it becomes possible to form a high quality film in which strain is not caused and cracks and dislocation densities are few. The condition under which the second underlying layer **43** is in lattice matching to the buffer layer **41** is Y=0.17. Therefore, it becomes possible to form the layer structure with high quality by using an $(In_{0.17}A_{0.83})_XGa_{1-X}N$ ($0<X \leqq 1$) film as the second underlying layer **42**. As a result, it becomes possible to form a nitride semiconductor device having few traps.

[0114] If the second underlying layer **43** is greater in band gap than the first underlying layer **42**, a difference is caused in conduction band energy at the interface between the second underlying layer **43** and the first underlying layer **42** according to the difference in band gap as shown in FIG. **27**. Therefore, carriers of the two-dimensional electron system can be formed at the interface between the second underlying layer **43** and the first underlying layer **42**. In the nitride semiconductor device according to the present embodiment shown in FIG. **19**, therefore, the pinch-off characteristics are degraded. It becomes possible to form a nitride semiconductor device in which residual carriers are few at the interface between the second underlying layer **43** and the first underlying layer **42** and the pinch-off characteristics are excellent by making the band gap in the second underlying layer **43** nearly the same as that in the first underlying layer **42** or making the band gap in the second underlying layer **43** smaller than that in the first underlying layer **42**.

[0115] In the present embodiment, the GaN film is used as the channel layer **44** and the AlGaN film is used as the barrier layer **45**. Alternatively, it is possible to use an In_PGa_QN film ($0<P<1$, $0<Q<1$) as the channel layer **44** and use an $In_UAl_WGa_VN$ film ($0 \leqq U<1$, $0 \leqq V<1$, $0<W \leqq 1$, $U+V+W=1$) as the barrier layer **45**. In this case, it is desirable that the In composition ratio U of the barrier layer **45** is 0.3 or less so as to have no difference in lattice constant from the buffer layer **41** and the Al composition ratio W is in the range of 0.1 to 0.4.

(First and Second Modifications)

[0116] A nitride semiconductor device according to a first modification of the fourth embodiment is shown in FIG. **28**, and a nitride semiconductor device according to a second modification of the fourth embodiment is shown in FIG. **29**. The nitride semiconductor device according to the first modification shown in FIG. **28** differs from that according to the fourth embodiment shown in FIG. **19** in that a recess structure is formed by removing a part of the barrier layer **45** and a gate electrode **48** is formed in the recess structure. The nitride semiconductor device according to the second modification shown in FIG. **29** differs from that according to the fourth embodiment shown in FIG. **19** in that an insulation film **49** is formed on the barrier layer **45** and a field plate electrode **50** is formed on the insulation film **49**. In the nitride semiconductor devices according to the first and second modifications as well, the effect of the favorable pinch-off characteristics is obtained if the first underlying layer **42** and the second underlying layer **43** are formed as described above. In the fourth embodiment and its modifications, therefore, the structure above the barrier layer **45** can be designed freely.

[0117] The foregoing description mainly concerns a transistor having three electrodes on the barrier layer **45**. However, it is evident that similar effects can be obtained even for, for example, a diode having two electrodes on the barrier layer **45**. For example, as shown in FIG. **31**, the diode has a configuration obtained from that in the fourth embodiment shown in FIG. **19** by providing an anode electrode **56** and a cathode electrode **57** instead of the source electrode **46**, the drain electrode **47** and the gate electrode **48**.

Fifth Embodiment

[0118] A nitride semiconductor device according to a fifth embodiment of the present invention is shown in FIG. **30**.